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Fungal communities of volcanic ash soils along an altitudinal gradient in Mexico

I. Composition and organisation

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With one figure

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1. Introduction

There are several available studies one the composition and organization of the fungal communities of conifer forest soils (CHRISTENSEN & WITTINGHAM, 1965; SÖDERSTRÖM, 1975; WIDDEN, 1979; WIDDEN & PARKINSON, 1973). In addition CHRISTENSEN (1981) discussed the distribution of the fungal species and characterized the soil microfungi of the main ecosystems of the world. Nevertheless little is known about the microfungi of volcanic ash soils, which are very frequent in the altitudinal conifer woodlands in Mexico (PEÑA-CABRIALES & VALDEZ, 1975). BETTUCCI (1985) has studied fungal communities colonizing wood stakes buried in soils whose mycological analysis will be carried out in this work.

The present study was undertaken to determine the composition and organization of the communities of the opportunistic decomposers (GOCHENAUR, 1978) of the AO horizon of 3 soils located on the western slope of volcano Popocatepetl (Mexico).

Subsequent contributions will supply analysis of the spacial distribution and the seasonal evolution of the fungal populations. Very likely the fungal communities may help to characterize these soils whose mineralogic composition is very peculiar (HETIER, 1973; DUCHAUFOUR & SOUCHIER, 1977, 1979).

2. Study area

Three sites were selected on an altitudinal gradient of 670 m along the western wall of volcano Popocatepetl, southeast of Mexico valley.

Site La Joya (LJ) is located at an altitude of 3660 m (19° 05′′ 44″ latitude north and 98° 39′ 05″ longitude west). The climate is temperate – cold with a short cool summer, subhumid, with an annual rainfall of 1187,5 mm and an annual mean temperature of 7,7 °C (GARCIA, 1981). The soils is an alpine Ranker (FLORES, 1974). The vegetation consists of law pastures associated with some *Pinus hartwegii* LINDLEY.

Site Nexpayantla (N) is located at 3300 m (19° 05′ 27″ latitude north and 98° 39′ 05″ longitude west). The climate is temperate – cold with a long cool summer subhumid, with annual mean temperature of 11,1 °C and an annual rainfall of 1169,3 mm. The soil is a humic Andosol (FLORES, 1974) and 3 vegetation strata are observed, herbaceous, shrub layer and arboreal, consisting of an association of *Abies religiosa* SCHL. *et* CHAM. with *Pinus hartwegii* LINDLEY and *P. montezumare* LAMBERT.

Site La Tijera (LT) is located at 2980 m (19° 04′ 04″ latitude north and 98° 40′ 51″ longitude west). The climate is similar to that of the former site and the soil is a vitric Andosol (FLORES, personal communication). The vegetation consists of an herbaceous stratum and planules of *Abies religiosa*, and an arboreal stratum of *Pinus hartwegii* planted 20 years ago.

The physicochemical properties of the AO horizon have been recorded previously by BETTUCCI (1983).

3. Materials and methods

During March, July and November 1983, at each site, 4 samples of about 1 kg were collected, at 1 m intervals along a line transect (nearly 100 m long) placed over open breaches on the volcano, and removed from the AO horizon. They were placed in polyethylene bags and transferred to the laboratory. They were kept at room temperature (20°C) until their processing on the next day when mycological analysis were done.

Fungal isolations were performed using the dilution plate method that CHRISTENSEN (1981) and CLARKE & CHRISTENSEN (1981) have suggested to be used for analysis and comparison of microfungal communities. GOCHENAUR (1978) pointed out the colonies obtained by this method are derived from fungi that had exploited substrates in the past and may do so in the future. So propagules density may be a useful indicator of individual's potential in the soil.

One gram dried soils samples were diluted to 10−4. For each sample, 5 Petri dishes (with 2% Agar-Malt medium at *p*H 5) were inoculated with one milliliter of the soil dilution. The dishes were maintained at room temperature until the fungal colonies developed and then, these colonies were successively numbered. Those with the same macromorphological characteristics and the same reaction with the culture media were ascribed the same number. Each different colony was subcultured to allow identification by means of conventional mycological methods. Cultures that failed to sporulate one month were considered as sterile mycelia.

Relative density (RD) of the species was calculated according to the formula:

$$RD = \frac{\text{number of isolates of one species} \times 100}{\text{Total number of isolates}}$$

The mycofloras of the 3 sites were compared by means of Sørensen's Index of Similarity: IS = 2C/A + B were A is the number of species at one site, B the number of species at the other site and C the number of shared species (CLARKE & CHRISTENSEN, 1981). In order to standardize the abundance of species at all three sites, the number of species was evaluated by number of species × 100/the number of isolates.

4. Results

From 36 soil samples collected in March, July and November, 3220 isolates were obtained. These were distributed as follows: 295 at La Joya, 1149 at Nexpayantla and 1776 at La Tijera. These isolates represent 49 taxa, of wich 26 came from La Joya, 25 from Nexpayantla and 23 from La Tijera. The majority of them belong to Deuteromycetes. The species from the Dematiaceae made up between 8,2% (Nexpayantla) and somewhat over 50% (La Joya and La Tijera) of the isolates. The Moniliaceae ranged from 39% (La Joya and La Tijera) to 83% (Nexpayantla). The species from the other taxonomic groups did not exceed 8% (Fig.1).

At the 3 sites the genus *Penicillium* was the one presenting the largest number of species: 10 species were isolated at La Joya (38,7% of the total isolates), 11 at Nexpayantla (76,3%) and 13 at La Tijera (28,5%). The genus *Oidiodendron,* although only represented by 4 species, was isolated in a similar proportion to *Penicillium* at La Joya (38,98%) and rated as the most abundant genus at La Tijera (58,9%).

The species isolated with relative density about 1% (dominant and minor species) are listed in table 1. About 50% of the species at the three sites were isolated with relative densities below 1% (rare species) and represented less than 5% of the total isolates. By contrast, 3 species *(Penicillium nigricans* strain 17, *Oidiodendron periconioides* and *Oidiodendron echinulatum)* at La Tijera together account for more than 50% of the total isolates.

The similarities among the three sites are shown in table 2. None of them was above 47%. The number of species per each 100 isolates varies markedly: La Joya 8,8; Nexpayantla 2,17 and La Tijera 1,29.

5. Discussion

Data exhibit differences among the fungal communities. However at the three sites the community structure follows the same Raunkier pattern (MULLER-DOMBOIS & ELLENBERG, 1974). At La Joya three species codominate the community namely: *O. periconioides, O. echinulatum* and *P. nigricans* strain 17. These species are present at the other sites as dominant, minor or rare

Table 1. Species isolated with relative densities above 1% (dominant and minor species).

	La Joya	Nexapayantla	La Tijera
Basidiomycete	2.37		
Sterile mycelium	1.36		
Mucor hiemalis WEHMER	1.36		
Cladosporium herbarum (PERS.) LINK *ex* GRAY	1.69		
Penicillium chrysogenum THOM	2.03		
Penicillium turbatum WESTLING	2.37		
Phialophora mustea NEERGAARD	4.75		
Phialophora lagerbergii (MELIN *et* NANNF) CONANT	4.41	1.04	
Oidiodendron echinulatum BARRON	20.68	1.74	
Oidiodendron periconioides MORRALL	17.97		57.77
Penicillium nigricans BAIN. *ex* THOM (strain 10)	6.10		4.45
Penicillium nigricans BAIN. *ex* THOM (strain 17)	25.42	58.66	8.73
Eupenicillium lasseni PADDEN	3.73	6.18	1.80
Trichoderma viride PERS. ex GRAY	1.02	6.96	4.45
Penicillium griseum (SOPP) THOM		14.36	1.07
Eupenicillium pinetorum STOLK		1.57	4.95
Humicola grisea TRAAEN		4.61	
Penicillium janthinellum BIOURGE (strain 133)			5.74
Penicillium janthinellum BIOURGE (strain 139)			1.24
Penicillium purpurogenum STOLL			4.17
Penicillium frequentans WESTLING			2.48
Oidiodendron tenuissimum (PECK) HUGHES			1.80
Paecilomyces sp.			1.13
Total isolates	**295**	**1149**	**1776**

Table 2. Indices of similarity between the fungal communities of the 3 sites

	Nexpayantla	La Tijera
La Joya	47.06	40.82
Nexpayantla		41.67

species. *O. periconioides* is the only dominant species at La Tijera (57,77% of the total isolates) while it is a rare species at Nexpayantla. *O. echinulatum* is a minor species at Nexpayantla and was not isolated at La Tijera. *P. nigricans* strain 17 is the only dominant species at Nexpayantla (58,66%) and is a minor species at La Tijera. *Eupenicillium lasseni* and *Trichoderma viride* are the minor species shared by the 3 soils simultaneously. However they have different densities in each one. The rare species accounted for 46% of all the species at La Joya, 68% at Nexpayantla and 43% at La Tijera. None of them are rare at 3 sites at the same time. Since in general only one isolate was derived from each, they do not have a decisive bearing on the characterization of the communities. GOCHENAUR (1978) contends that this type of distribution of the fungal species is the result of a greater specialization of the most abundant species designed to colonize a varied range of resources, forcing the reminder to occupy a peripheral position.

The total number of propagules of the species increases with decreased altitude, while the number of species is nearly the same. However, the apparently greater diversity, estimated by the number of species per cent isolates (GOCHENAUR, 1978), observed at La Joya is derived from the variation in the community composition at the 3 sampling times (unpublished data). This variation may be due to the marked changes of the temperature and humidity which includes soil water freezing

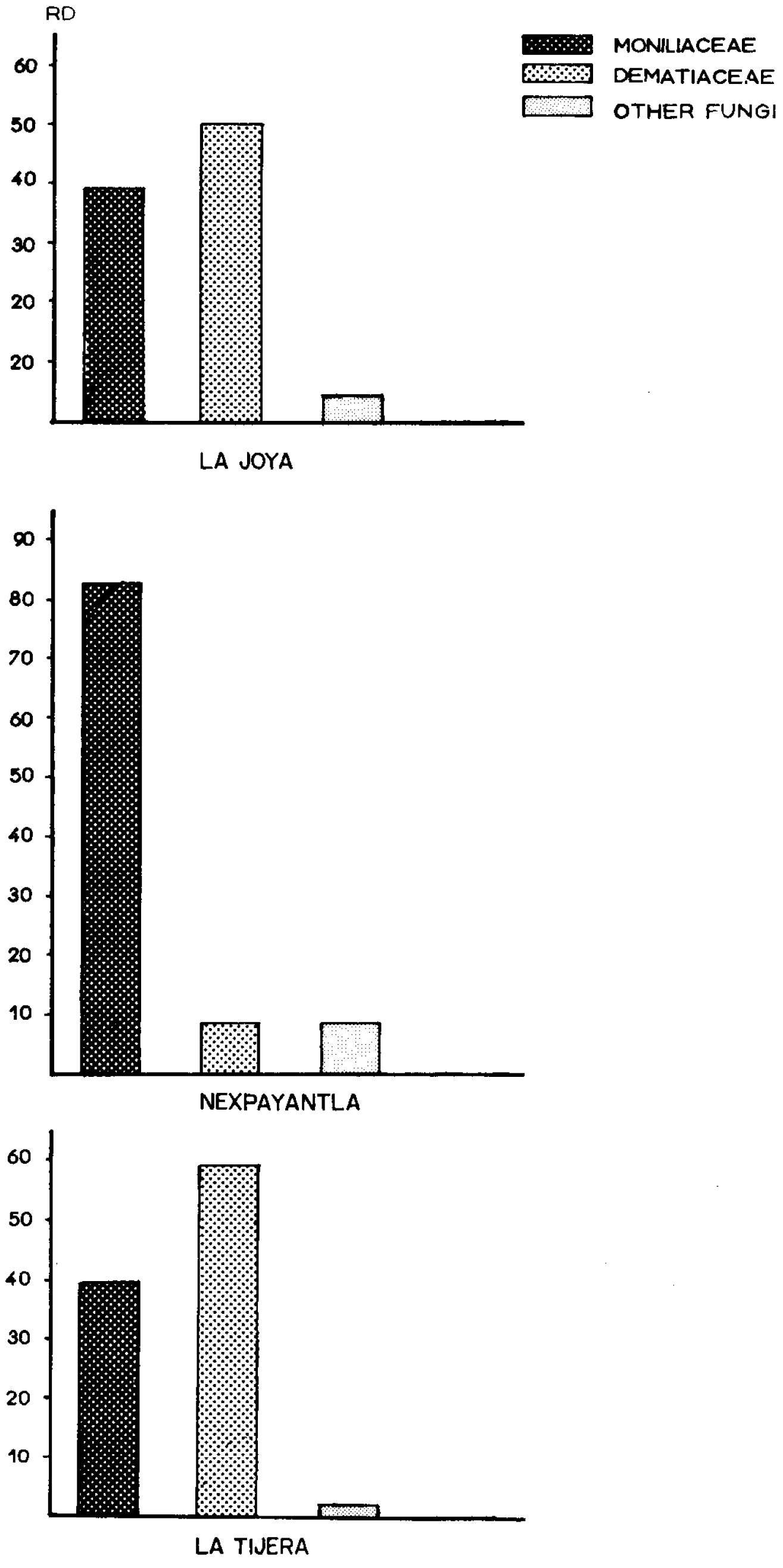

Fig. 1. Distribution of fungal isolates among the main taxa.

during the winter months. On the other hand the transition from *Pinus hartwegii* woodland to grassland constitutes another factor of variability in the composition of this community of opportunistic decomposers.

One of the characteristics common to fungal communities of woodland soils is the dominance of the Mucorales and/or Moniliacaea species (GOCHENAUR, 1981). Nevertheless she also remarks that the former are more common in the boreal woodlands or those dominated by conifers while the latter are characterisitc of broad-leaf woodlands of temperate regions. This generalization does not apply to this study as it was only possible to obtain four isolates of *Mucor hiemalis* (at La Joya) while the Moniliaceae added up to 54% of the total isolates. Within these, GOCHENAUR (1981) and CLARK & CHRISTENSEN (1981) point out that *Penicillium* constitutes one of the main genera of this type of community. In particular, *P. nirgicans* exhibits a broad distribution in soils of temperate regions (DOMSCH *et al.*; 1980) and was also found in an Andosol but with lower density (MARTINEZ & RAMIREZ, 1979). Our results agree with these findings as we found *P. nigricans* at the 3 sites but with less relative density at La Tijera. Of all the Species of this genus wich constitute minor species, *P. griseum* was the most abundant and was isolated at Nexpayantla and to a much lower extent at La Tijera. By contrast, *P. janthinellum* strain 133, *P. purpurogenum* and *P. frequentans* were represented to a greater degree at La Tijera than at Nexpayantla. At La Joya, *P. turbatum* an *P. chrysogenum* were the only minor *Penicillium* species and were scarcely isolated at the other sites. Moreover if we take into account that 66% of the rare species at La Joya, 58,8% at Nexpayantla and 70% at La Tijera belong to the genus *Penicillium* it is seen that a significant number of the species isolated belong to this taxon.

Oidiodendron, a dominant genus at La Joya and La Tijera, is characteristic of conifer forest soils and broad-leaf woodlands (CHRISTENSEN et al., 1965; GOCHENAUR, 1981) but not of Andosols (MARTINEZ & RAMIREZ, 1979). MANGENOT & REISINGER (1976) point out that the common occurrence of species of *Oidiodendron* in forest soils may be related to the claim of consumption and dispersal of *Oidiodendron* conidia by certain kinds of mites. Moreover it is possible to assume that at La Tijera a great disturbance was introduced when *Pinus hartwegii* was planted in the *Abies religiosa* woodland. GOCHENAUR (1981) contends that melanized taxa may increase in importance since species may possess physiological and/or nutritional means of adaptation allowing them to compete successfully or possibly merely survive for a longer period of time in the modified environment.

On the other hand, *Trichoderma* was isolated at the three sites as a minor species. Nevertheless we are dealing with a genus frequently cited in conjunction with temperate woodland soils (WIDDEN & PARKINSON, 1973. WIDDEN & ABITBOL, 1980) with higher densities than those found herein.

Paecilomyces, a common genus of conifer woodland soils (CHRISTENSEN & WITTINGHAM, 1965; CHRISTENSEN, 1981; WIDDEN, 1986) was only isolated as a minor low-density species at La Tijera.

The differences between the fungal communities of the three soils is assumed to be fundamentally ascribable to the differences between the sites. Several species are common to more than one soil, as reflected by relatively high indices of similarity. However at each site they were isolated with different abundances and hence they make up unequal fungal communities. This was also observed by BETTUCCI (1985) when dealing with the communities colonizing buried stakes in these same soils under laboratory conditions. She found significant differences in the community organizations using Correspondence Analysis. Nevertheless the species concerned in her study were not found within the communities in the same proportion nor were all isolated in the present study.

Factors such as seasonality and spatial distribution may affect the composition and/or organization of the communities. Subsequent papers will try to analyse those influences.

6. Résumé

[Communatés fongiques isolées d' un sol volcanique au Mexique, suivant un gradient altitudinal]

Les communautés fongiques de trois sols d'origine volcanique, suives sur le flanc du volcan Popocatepetl (Mexique), à trois saisons différentes sont étudiées. Les sites sont étagés sur un dénivellé de 670 m. L' organisation

des trois communautés suit la distribution de Raunkier. *Penicillium nigricans, Oidiodendron periconioides* et *O. echinulatum* sont les plus abondantes. Dans les trois sites les espèces les plus nombreuses sont des *Penicillium*. La moitié des espéces sont présentes avec une très faible densité relative (5%). D' importantes interactions se produisent à chaque site de telle sorte que les mêmes espèces forment des communautés différentes dans chaque sol.

Mots clefs: Communautés fongiques, sols volcaniques, *Penicillium nigricans, Oidiodendron periconioides, Oidiodendron echinulatum.*

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Synopsis: *Original scientific paper*

RODRIGUEZ, CL., L. BETTUCCI & M.-F. ROQUEBERT, 1990. Fungal communities of volcanic ash soils along an altitudinal gradient in Mexico. I. Composition and organization. Pedobiologia **34**, 43–49.

Fungal communities of 3 soils with volcanic ashes as basal material were studied. The samples were collected on the western side of volcano Popocatepetl during the rainy seasona (July), after the rains (November) and during the dry season (March). The 3 sites were located along an altitudinal gradient of 670 m. The organization of the 3 communities follows a Raunkier's distribution. *Penicillium nigricans, Oidiodendron periconioides* and *Oidiodendron echinulatum* were the most abundant species. *Penicillium* was the genus represented by the larger number of species at the 3 sites. Nearly 50% of the species were isolated with very low relative densities (rare species) and they accounted for only the 5% of all isolates obtained. Important interactions have occurred at the sites and and consequently the same species give rise to different communities at each soil.

Key words: Fungal community, volcanic ash soils, *Penicillium nigricans, Oidiodendron periconioides, Oidiodendron echinulatum.*

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